Multi-robot Operator Control Unit (MOCU)

SPAWAR Systems Center, San Diego

MOCU Features

- Command and control of unmanned vehicles and sensors
- Multi-vehicle support
- Vehicle and protocol type agnostic
- Reconfigurable and dynamic user interface
- Modular architecture (maps, protocols, video, etc.)
- Scalable
- Distributed development

Modular Architecture

Map Modules
- DNC (COGENT)
- C/JMTK (ESRI)
- GeoTIFF

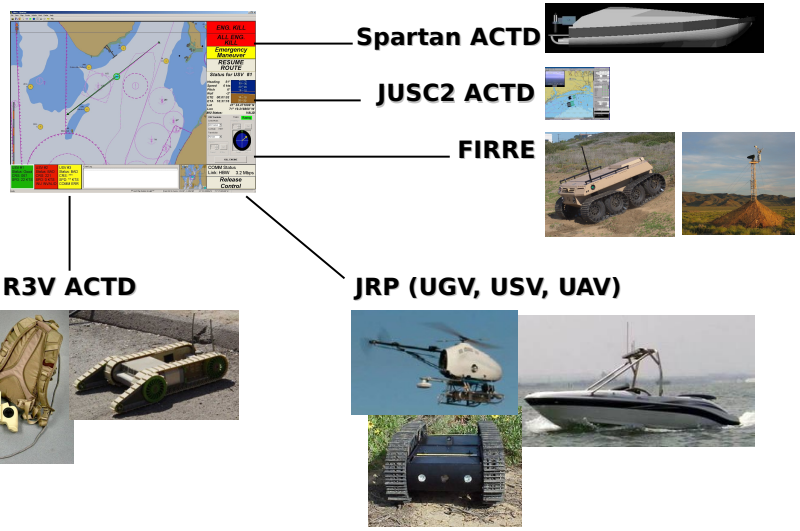
MOCU Core

Protocol Modules
- JAUS
- MRHA/SMART
- iRobot Aware

Media Modules
- MJPEG
- H.263
- IndigoVision codecs

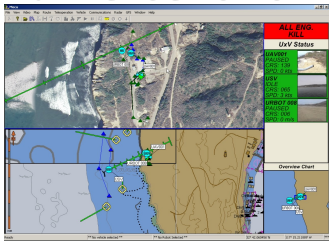
C2 Link Modules
- JUSC2 UVCC (Spartan)
- Composeable Forcenet (CFn)

Programs using MOCU



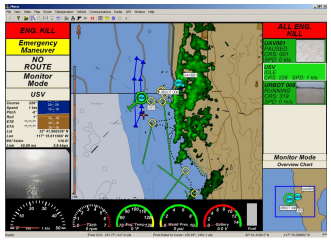
Reconfigurable User Interface (Dynamic)

Multi-vehicle Monitor Mode



UGV Control

USV Control w/ radar overlay



FIRRE Remote Sensor Monitorin

Multi-robot Operator Control Unit (MOCU)

SPAWAR Systems Center, San Diego

Multi-vehicle Control

- **Designed for multi-vehicle control**
  - Vehicle type and protocol independent
- **Configurable and dynamic user interface (UI)**
  - UI easily tailored to vehicle types or vehicle configurations
    - Buttons, Gauges, Video, Maps, Toolbars, etc.
  - UI dynamically reconfigures based on vehicle type or vehicle mode
  - Icon and chart based interface rather than menu based
    - Majority of vehicle commands issued via chart interaction or toolbar icons
    - Vehicles selected for control by double clicking chart icon or status summary
    - Detailed vehicle status information displayed in mouse-over pop-up windows
- **Monitor Mode**
  - An additional UI configuration for maintaining situational awareness of all vehicles when not in direct control of any one vehicle
  - Overview map(s), vehicle status summaries (color coded), event window, etc.
- **Control Handoff**
  - Developed for Spartan to hand control of a vehicle from one MOCU to another
- **Network agnostic**
  - MOCU is not tied to any specific network type, protocol or radio
  - Communications to vehicles and other C2 systems is performed via plug-and-play software modules

Multi-robot Operator Control Unit (MOCU)

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USV specific control

- Nautical chart support (NGA Digital Nautical Charts (DNC) and IHO S-57)
  - Uses SSC Charleston COGENT mapping engine
- Multiple control modes
  - Waypoint routes
    - Point and click
    - Manual keyboard entry
    - Load from file or template
  - Low-level control
    - Vector drive (auto heading)
    - Direct actuator control (throttle, steering, bucket)
- Wrote JAUS IDD for USVs
  - Extended JAUS messaging set for USV-specific requirements
- Radar overlay
  - Raw radar image and contacts
- User defined operation and exclusion zones
- Obstacle avoidance route modification interface
  - Allows USV to suggest route modifications to operator

Multi-robot Operator Control Unit (MOCU)

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High-level C2 Interfaces

- JUSC2 (implemented)
  - USV status sent from MOCU to JUSC2
  - Waypoint routes sent from JUSC2 to MOCU
  - Interface via Spartan proxy server
  - NMEA protocol
- Composeable Forcenet (CFn) (in progress)
  - Waypoints, missions and GCCS tracks sent from CFn to MOCU
  - USV status and video sent from MOCU to CFn
  - XML protocol
  - Video conversion and forwarding module
  - Chat
- Uses MOCU C2 link plug-and-play module
  - Interfaces to one or more high-level C2 systems
  - Can easily develop new C2 interfaces

Multi-robot Operator Control Unit (MOCU)

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Scalability

- Modularity allows MOCU to scale to requirements
- Only required modules are loaded
- Allows MOCU to run on small embedded systems, laptops or racks

Multi-robot Operator Control Unit (MOCU)

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Vehicles and Systems Controllable via MOCU

- URBOT (SSC - JRP)
- Packbot (iRobot)
- MDARS-E (PM-FPS, GDRS)
- Rotomotion VTOL UAV (SSC – JRP)
- Spartan ACTD USV (NUWC – OSD)
- Sentinel USV (AAC – SBIR)
- SSC USV (JRP)
- FIRRE TAGS (PM-FPS, Northrup)
- ATRV (SSC, INL – JRP, DOE)
- CETUS UUV (SSC)
- JAUS vehicles (OPC experiments)
- Planned
  - Arcturus T-15 UAV (INL)
  - Electric VTOL UAV (INL)
  - R-Gator (iRobot, John Deere – CNI)
  - LCS USV (ASW, MIW)
- MPP (SSC – DTRA)
- NROWS (SSC – DTRA)
- BAIS (FIRRE – PM-FPS)
- AN-PPS5D (FIRRE – PM-FPS)
- VTOL UAV automated refueling fixture (SSC – JRP)

Multi-robot Operator Control Unit (MOCU)

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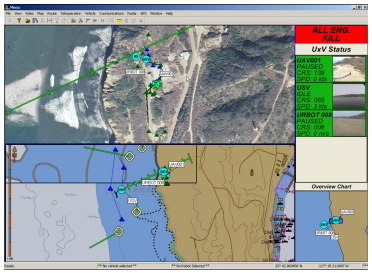
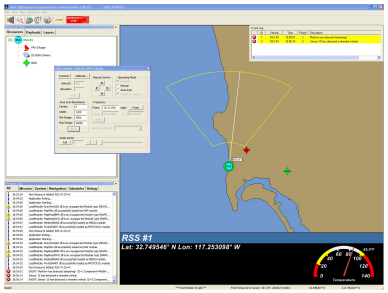
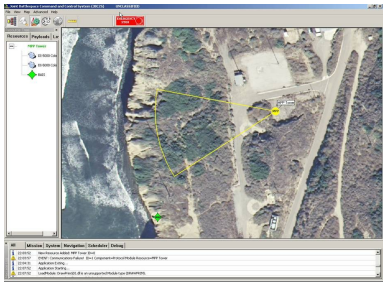
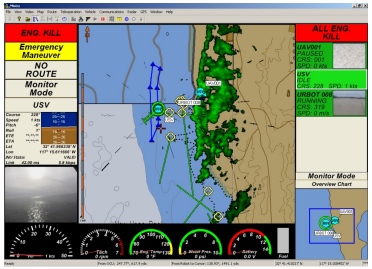
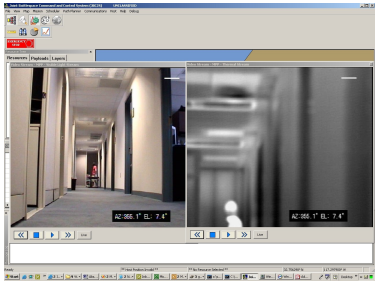
UI Configurability

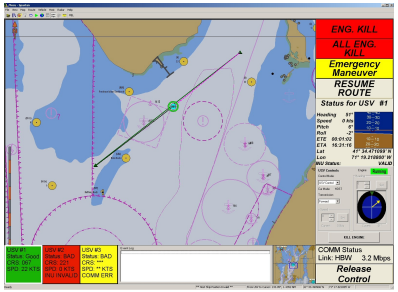












Multi-robot Operator Control Unit (MOCU)

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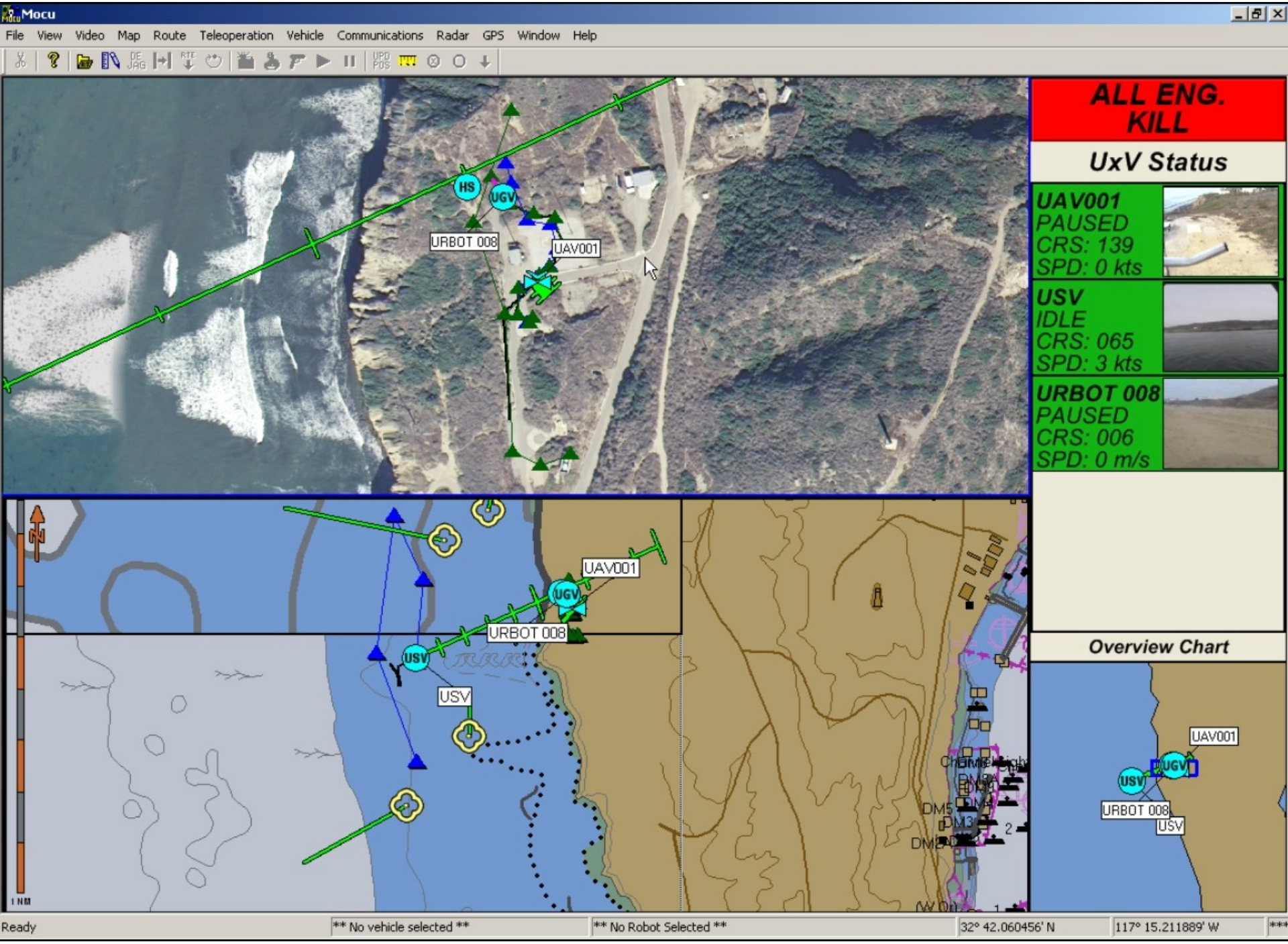
Dual Screen MOCU Concept

Questions?


Mocu
File View Video Map Route Teleoperation Vehicle Communications Radar GPS Window Help
HS
UGV
URBOT 008
UAV001
ALL ENG. KILL
UxV Status
UAV001
PAUSED
CRS: 139
SPD: 0 kts
USV
IDLE
CRS: 065
SPD: 3 kts
URBOT 008
PAUSED
CRS: 006
SPD: 0 m/s
UAV001
UGV
URBOT 008
USV
USV
Overview Chart
UAV001
UGV
USV
URBOT 008
USV
1 NM
Ready
** No vehicle selected **
** No Robot Selected **
32° 42.060456' N
117° 15.211889' W

Mocu

File View Video Map Route Teleoperation Vehicle Communications Radar GPS Window Help

ENG. KILL

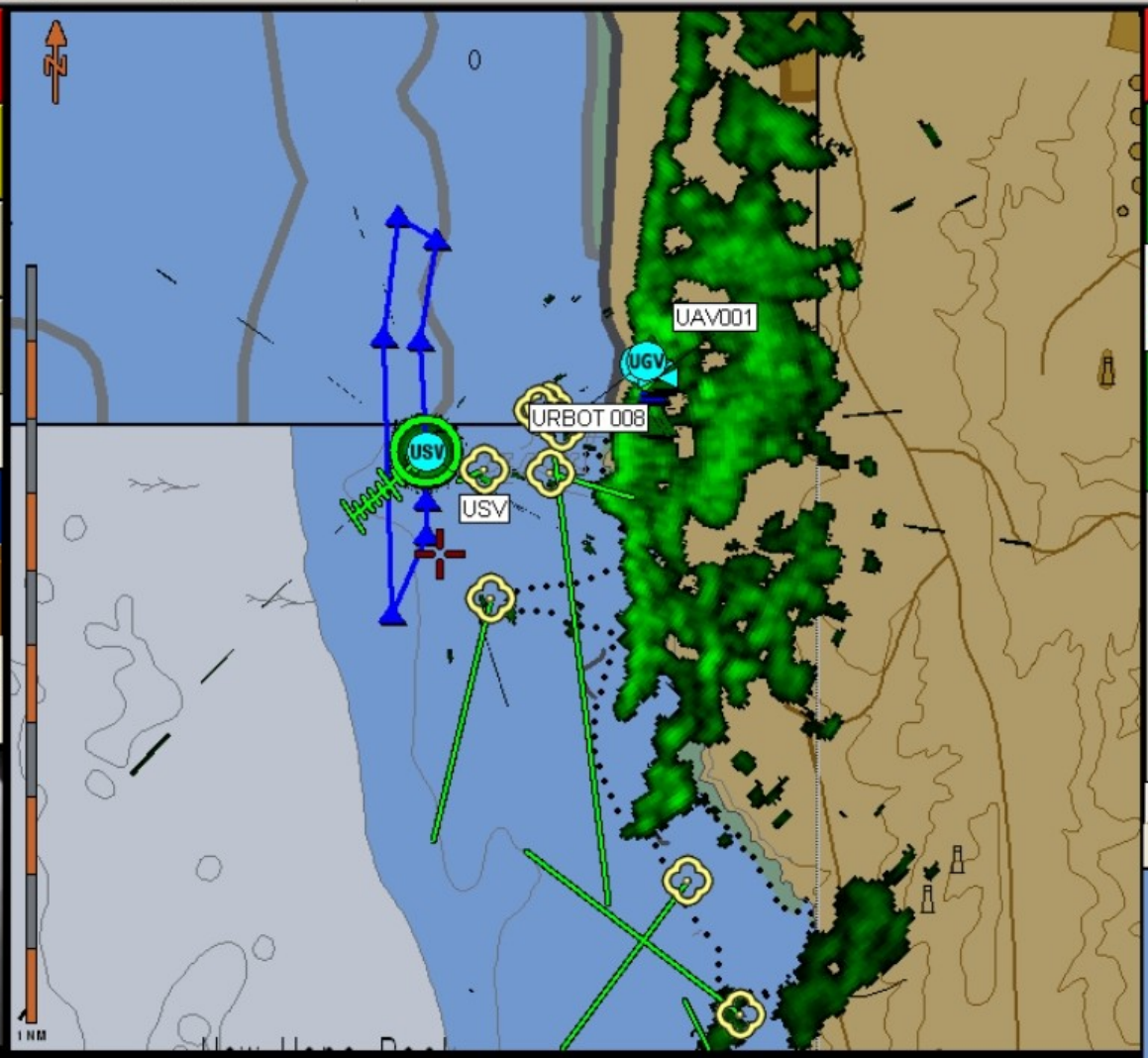
Emergency Maneuver

NO ROUTE

Monitor Mode

USV

Course	228°
Speed	1 kts
Pitch	-6°
Roll	1°
ETE	**:**:**
ETA	**:**:**
Lat	32° 41.966338' N
Lon	117° 15.611666' W
INU Status	VALID
Link	42.00 ms 5.8 kbps



ALL ENG. KILL

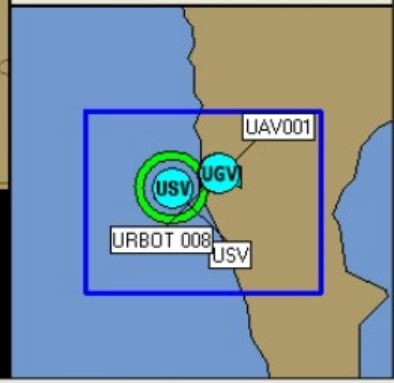
UAV001
PAUSED
CRS: 001
SPD: 0 kts

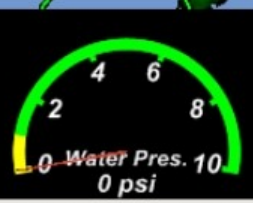
USV
IDLE
CRS: 228 SPD: 1 kts

URBOT 008
RUNNING
CRS: 319
SPD: 0 m/s

Monitor Mode

Overview Chart





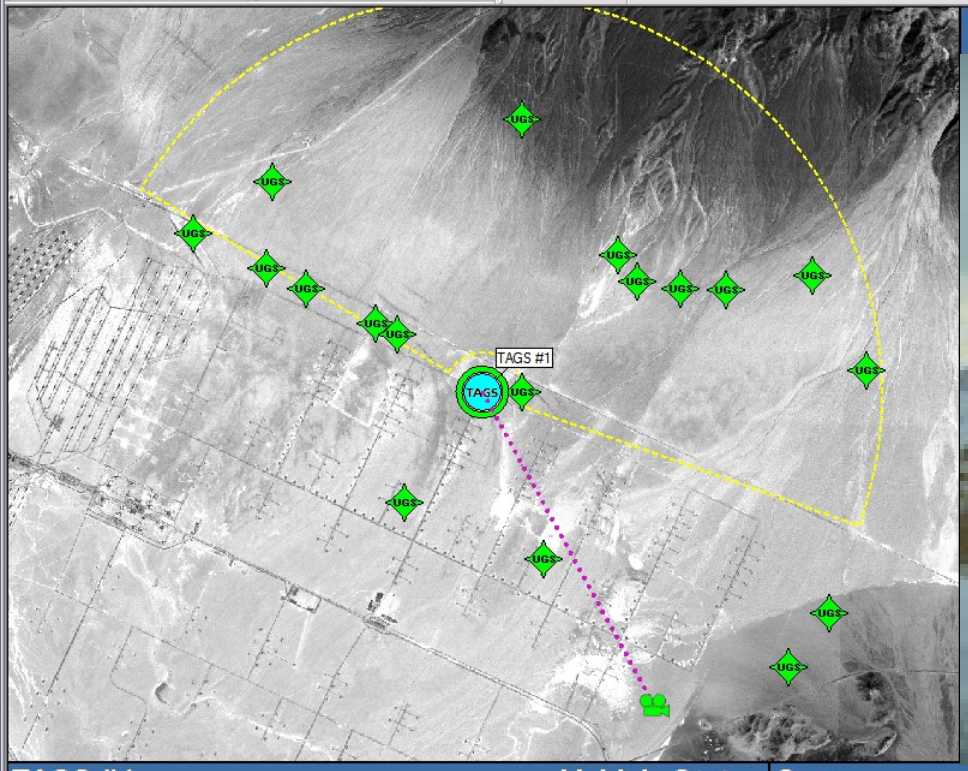
Ready | From OCU: 247.77°, 617.9 yds | From Robot to Cursor: 138.93°, 1491.1 yds | 32° 41.410217' N | 117° 15.038452' W

Mocu
File View Video Map Route Teleoperation Vehicle Communications Radar GPS Window Help
URBOT
Vel 0.0 m/s
Hdg 306°
Lat 32° 42.087229' N
Lon 117° 15.266908' W
Link 6.28 ms 8.0 kbps
Heading
306°
0.0 m/s
ALL ENG. KILL
UAV001
PAUSED
CRS: 057
SPD: 0 kts
USV
IDLE
CRS: 024
SPD: 2 kts
URBOT 008
PAUSED
CRS: 306 SPD: 0 m/s
UGV
HS
URBOT 008
UAV001
Monitor Mode
Overview Chart
USV
URBOT 008
USV
Ready
From OCU: 60.86°, 19.8 m
From Robot to Cursor: 64.32°, 602.5 m
32° 42.228470' N
117° 14.919434' W

Joint Battlespace Command and Control System (JBC2S) UNCLASSIFIED

File View Map Path Planner Advanced Help

EMERGENCY STOP



SeaFLIR Daylight

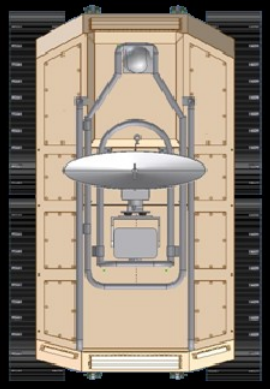
TAGS #1

Mode:	IDLE
Location:	11SLC 65771 71407
Elevation:	0 m
Heading:	114°
Velocity:	0.0 m/s
Engine Battery Voltage	0.0 volts
Mission Battery Voltage	0.0 volts

Vehicle Status

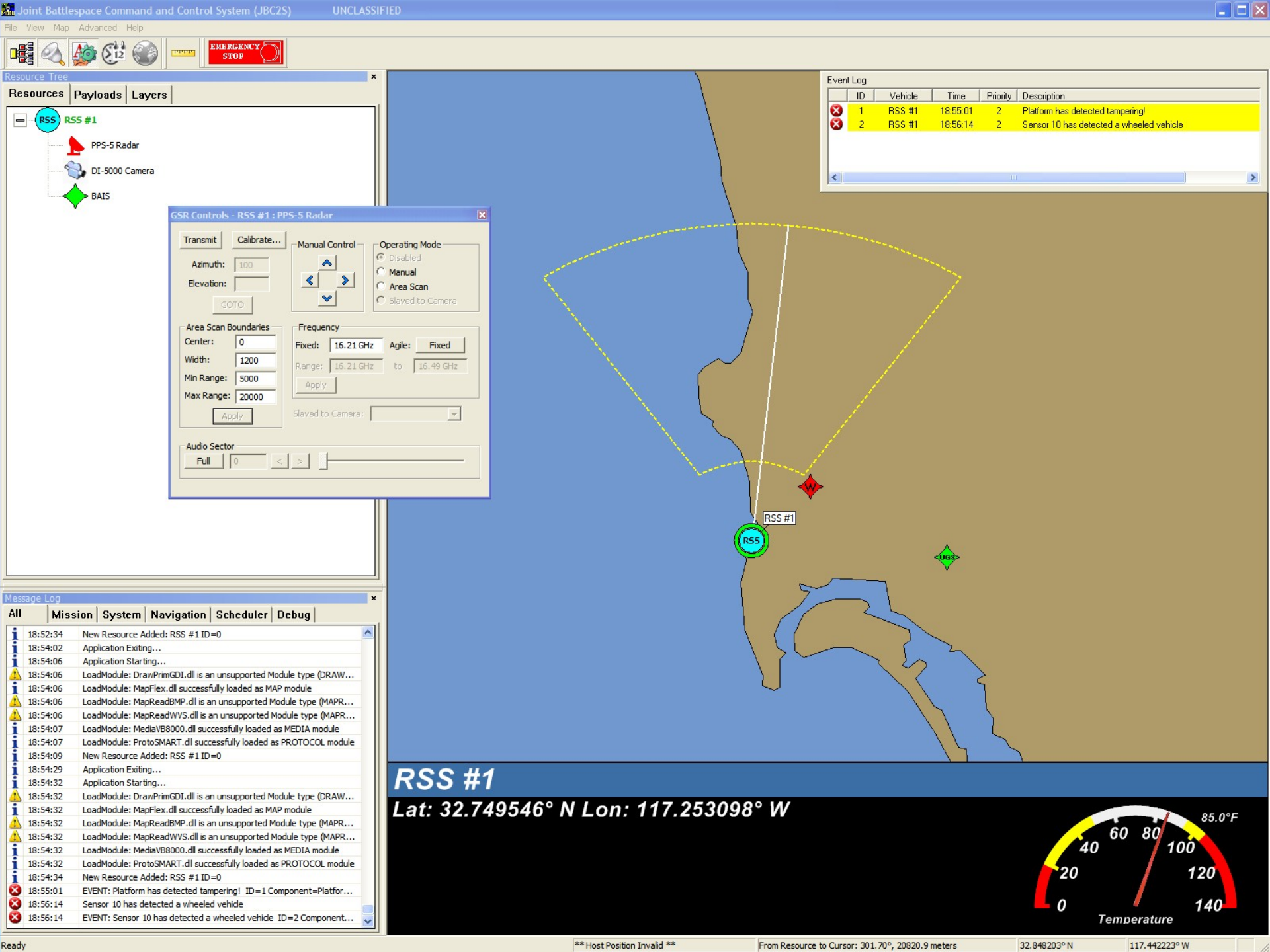
Gauges

TAGS Diagram



Comms GPS INU OD Temp Fuel Battery Engine

Ready | ** Host Position Invalid ** | From Resource to Cursor: 150.46°, 4466.5 m | 11SLC 67908 67486 | ** Elevation Unknown **


Joint Battlespace Command and Control System (JBC2S)
UNCLASSIFIED
File View Map Advanced Help
EMERGENCY STOP
Resource Tree
Resources Payloads Layers
RSS #1
PPS-5 Radar
DI-5000 Camera
BAIS
GSR Controls - RSS #1 : PPS-5 Radar
Transmit
Calibrate...
Azimuth: 100
Elevation:
GOTO
Manual Control
Operating Mode
Disabled
Manual
Area Scan
Slaved to Camera
Area Scan Boundaries
Center: 0
Width: 1200
Min Range: 5000
Max Range: 20000
Apply
Frequency
Fixed: 16.21 GHz
Agile: Fixed
Range: 16.21 GHz to 16.49 GHz
Apply
Slaved to Camera:
Audio Sector
Full
Event Log
ID Vehicle Time Priority Description
1 RSS #1 18:55:01 2 Platform has detected tampering!
2 RSS #1 18:56:14 2 Sensor 10 has detected a wheeled vehicle
RSS #1
UGS
Message Log
All Mission System Navigation Scheduler Debug
18:52:34 New Resource Added: RSS #1 ID=0
18:54:02 Application Exiting...
18:54:06 Application Starting...
18:54:06 LoadModule: DrawPrimGDI.dll is an unsupported Module type (DRAW...
18:54:06 LoadModule: MapFlex.dll successfully loaded as MAP module
18:54:06 LoadModule: MapReadBMP.dll is an unsupported Module type (MAPR...
18:54:06 LoadModule: MapReadWVS.dll is an unsupported Module type (MAPR...
18:54:07 LoadModule: MediaVB8000.dll successfully loaded as MEDIA module
18:54:07 LoadModule: ProtoSMART.dll successfully loaded as PROTOCOL module
18:54:09 New Resource Added: RSS #1 ID=0
18:54:29 Application Exiting...
18:54:32 Application Starting...
18:54:32 LoadModule: DrawPrimGDI.dll is an unsupported Module type (DRAW...
18:54:32 LoadModule: MapFlex.dll successfully loaded as MAP module
18:54:32 LoadModule: MapReadBMP.dll is an unsupported Module type (MAPR...
18:54:32 LoadModule: MapReadWVS.dll is an unsupported Module type (MAPR...
18:54:32 LoadModule: MediaVB8000.dll successfully loaded as MEDIA module
18:54:32 LoadModule: ProtoSMART.dll successfully loaded as PROTOCOL module
18:54:34 New Resource Added: RSS #1 ID=0
18:55:01 EVENT: Platform has detected tampering! ID=1 Component=Platfor...
18:56:14 Sensor 10 has detected a wheeled vehicle
18:56:14 EVENT: Sensor 10 has detected a wheeled vehicle ID=2 Component...
RSS #1
Lat: 32.749546° N Lon: 117.253098° W
85.0°F
0 20 40 60 80 100 120 140
Temperature
Ready
** Host Position Invalid **
From Resource to Cursor: 301.70°, 20820.9 meters
32.848203° N
117.442223° W

Joint Battlespace Command and Control System (JBC2S) UNCLASSIFIED

File View Map Mission Scheduler Path Planner Communications Host Help Debug

EMERGENCY STOP

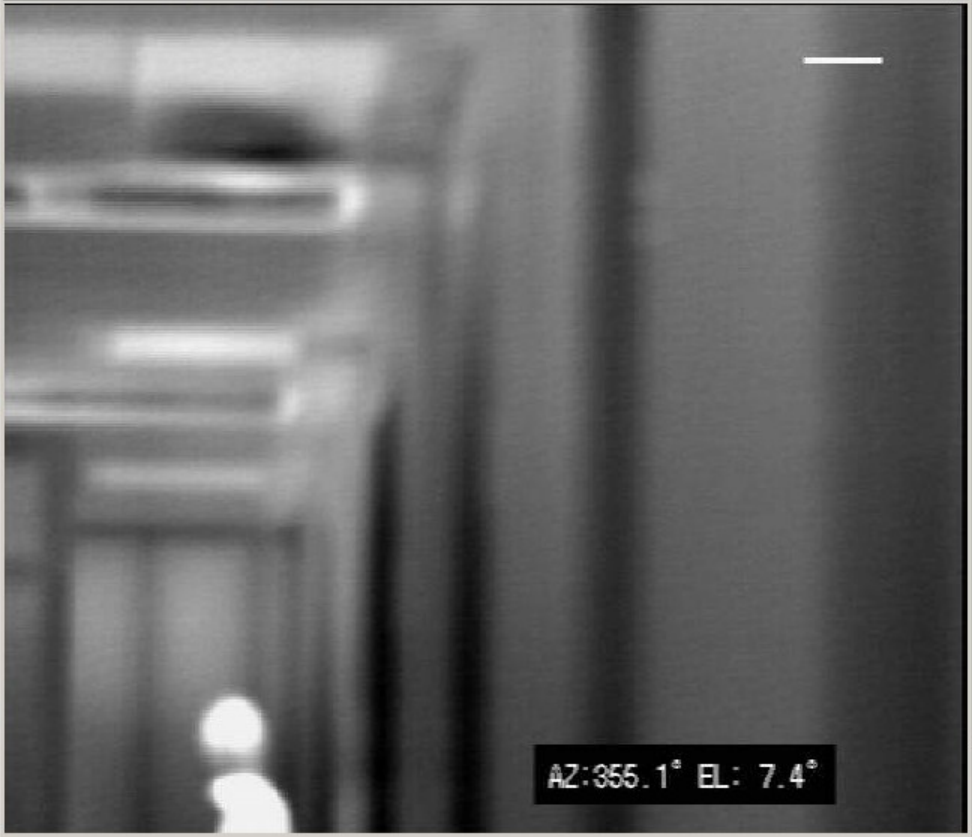
Resource Tree

Resources | Payloads | Layers

Video Stream - MPP - Visible Light Stream

Live

Video Stream - MPP - Thermal Stream



Live

Message Log

Ready | ** Host Position Invalid ** | ** No Resource Selected ** | 32.756298° N | 117.297900° W

Start | 2 I.. | 9 W.. | Abs... | 2 M.. | 2 N.. | Inb... | Mic... | 2 M.. | 3 g.. | c:\s... | C:\... | Joi... | Win... | Win... | Ad... | Desktop

Mocu

File View Video Map Route Teleoperation Vehicle Communications Radar GPS Window Help

UAV

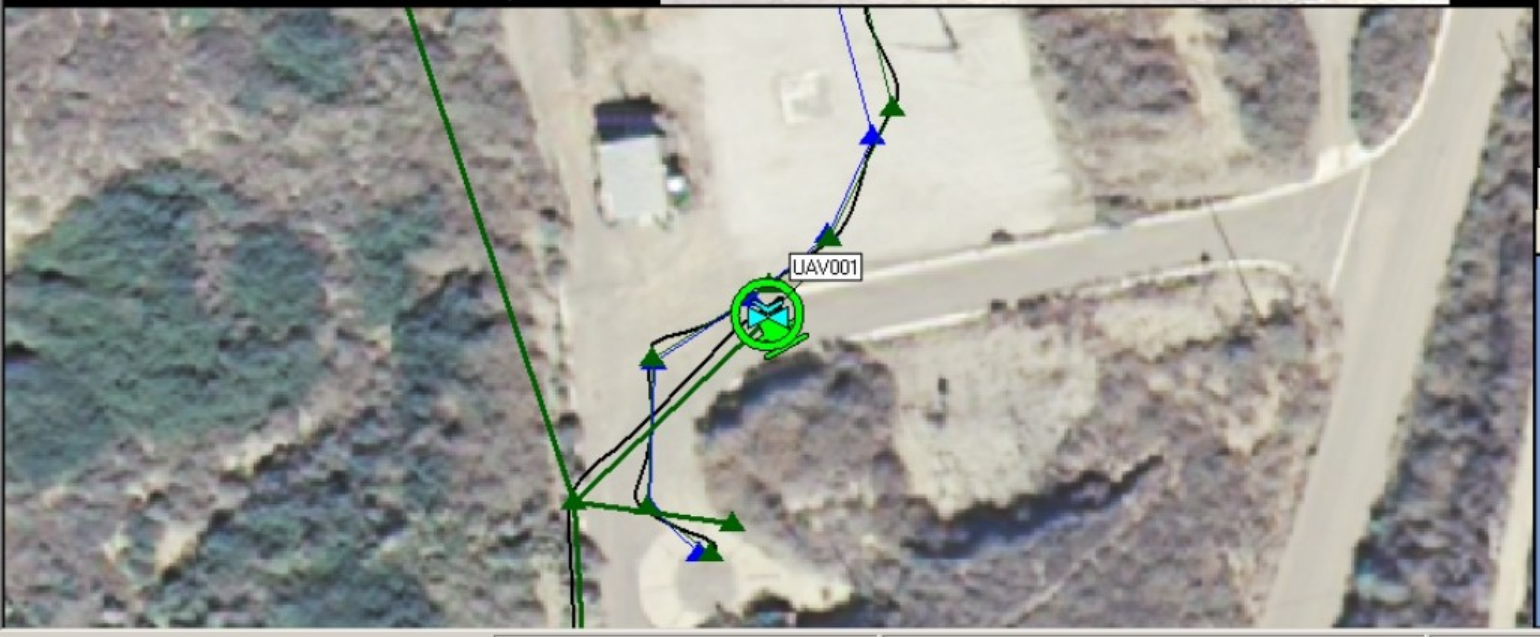
Speed	0 kts
Hdg	62°
Course	140°
Altitude (MSL)	19 ft
Lat	32° 42.052965' N
Lon	117° 15.250357' W

ALL ENG. KILL

UAV001
PAUSED
CRS: 140 SPD: 0 kts

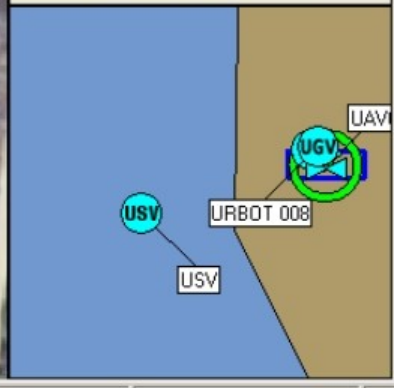
USV
IDLE
CRS: 099
SPD: 0 kts

URBOT 008
PAUSED
CRS: 310
SPD: 0 m/s

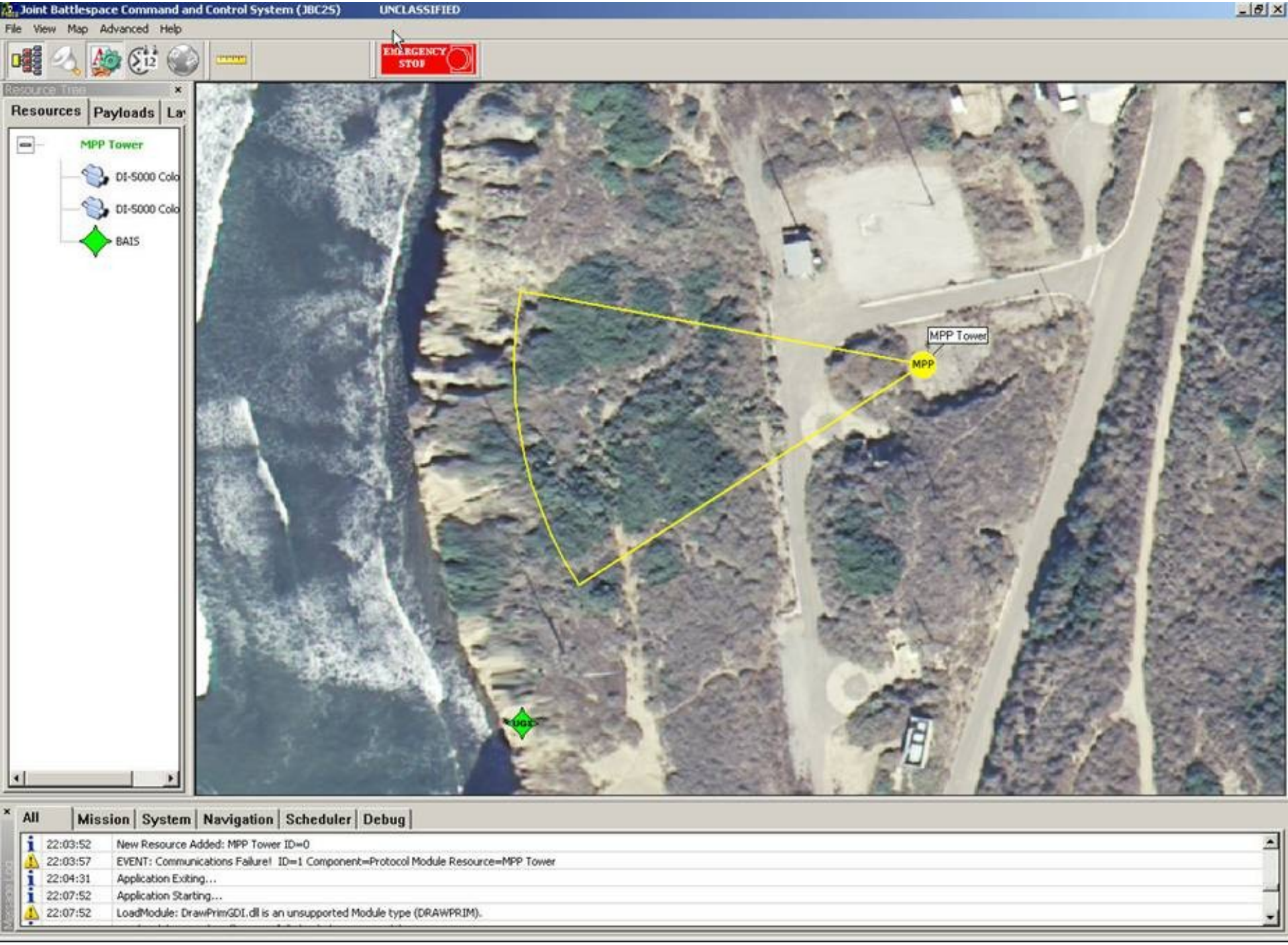


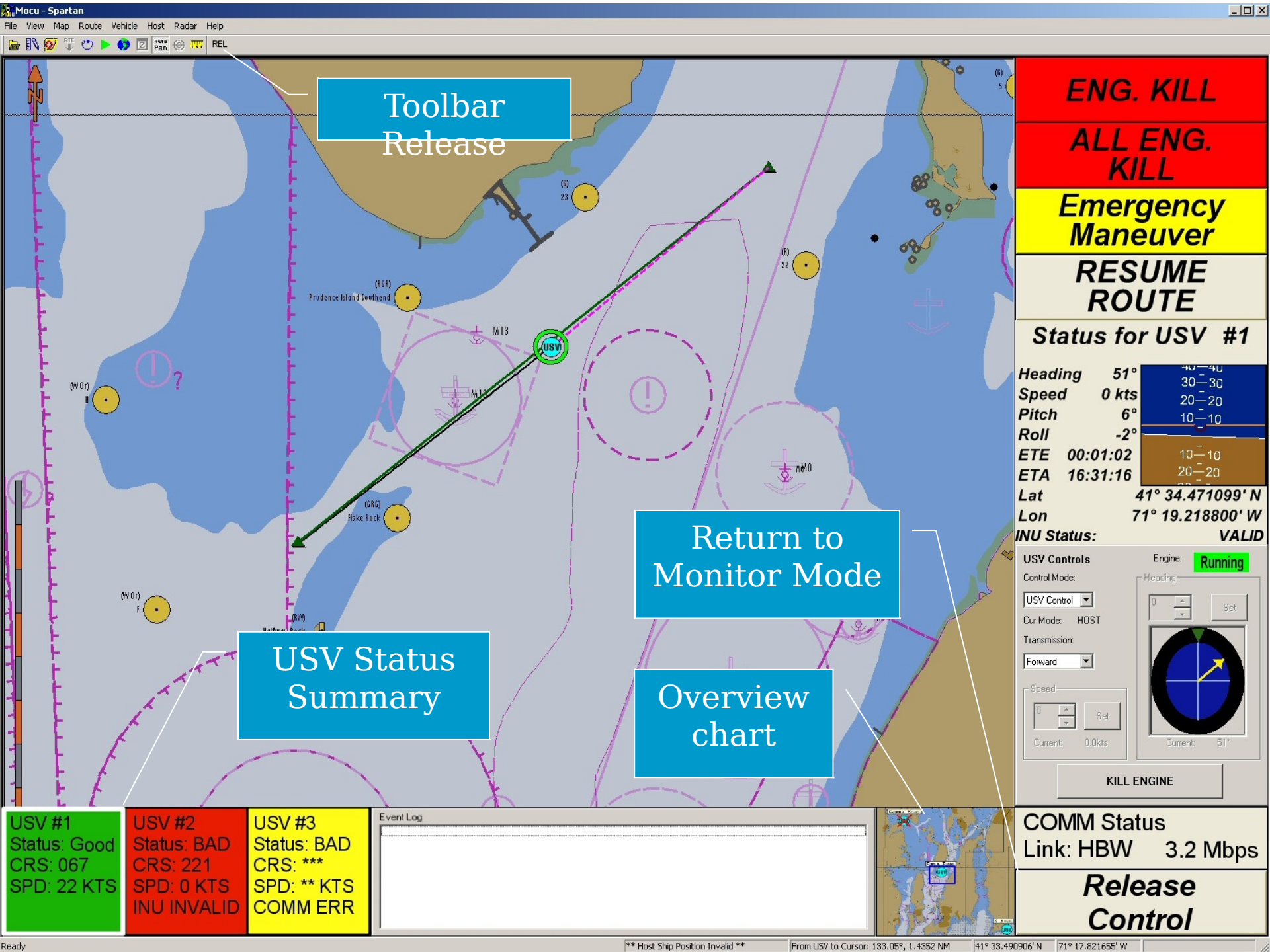
Monitor Mode

Overview Chart



Ready | From OCU: 141.17°, 75.3 yds | From Robot to Cursor: 57.90°, 667.6 yds | 32° 42.228470' N | 117° 14.919434' W


Joint Battlespace Command and Control System (JBC2S)
UNCLASSIFIED
File View Map Advanced Help
EMERGENCY STOP
Resource Tree
Resources Payloads La
MPP Tower
DI-5000 Colo
DI-5000 Colo
BAIS
MPP Tower
MPP
All Mission System Navigation Scheduler Debug
22:03:52 New Resource Added: MPP Tower ID=0
22:03:57 EVENT: Communications Failure! ID=1 Component=Protocol Module Resource=MPP Tower
22:04:31 Application Exiting...
22:07:52 Application Starting...
22:07:52 LoadModule: DrawPrimGDI.dll is an unsupported Module type (DRAWPRIM).


Mocu - Spartan
File View Map Route Vehicle Host Radar Help
REL
Toolbar Release
ENG. KILL
ALL ENG. KILL
Emergency Maneuver
RESUME ROUTE
Status for USV #1
Heading 51°
Speed 0 kts
Pitch 6°
Roll -2°
ETE 00:01:02
ETA 16:31:16
Lat 41° 34.471099' N
Lon 71° 19.218800' W
INU Status: VALID
USV Controls
Engine: Running
Control Mode:
USV Control
Cur Mode: HOST
Transmission:
Forward
Heading
Set
Speed
Set
Current: 0.0kts
Current: 51°
KILL ENGINE
Return to Monitor Mode
USV Status Summary
Overview chart
USV #1
Status: Good
CRS: 067
SPD: 22 KTS
USV #2
Status: BAD
CRS: 221
SPD: 0 KTS
INU INVALID
USV #3
Status: BAD
CRS: ***
SPD: ** KTS
COMM ERR
Event Log
COMM Status
Link: HBW 3.2 Mbps
Release Control
Ready
** Host Ship Position Invalid **
From USV to Cursor: 133.05°, 1.4352 NM
41° 33.490906' N
71° 17.821655' W

Video Integration in MOCU

- Pros
  - Automatic video control if desired
    - Train other sensors to point to mouse position on video (USV.SS.025500)
    - Select driving camera when vehicle selected
    - Video throttling (turn down frame rate when less supervision is required)
  - Absolute control over UI
    - Automatically resize, move, hide, etc video based on mode
    - Single application avoids focus shift
  - Consistent UI
    - Bitrate, zoom, camera select, etc
    - Reduces training
  - Built-in video relaying to other C2 systems in a consistent format
    - Video recording
    - Snap shots
  - Fewer accreditation and logistics issues

- Cons
  - Additional integration required
    - level of effort depends on access to CODEC SDK
      - Note: CODEC vendor could supply the MOCU plug-in